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THESIS

DEFENSE DATA NETWORK:
USAGE SENSITIVE BILLING

by

Kathryn McNamara

June 1986

Thesis Advisor: C. Wunderly

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Defense Data Network: Usage Sensitive Billing

by

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Lieutenant, United States Navy
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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

The Defense Data Network (DDN) program plan approved by the Office of the Secretary of Defense (OSD) on 2 April 1982 and subsequent OSD policy guidance on DDN provides for the eventual recovery of applicable network costs by billing of subscribers based upon their utilization of network resources. This thesis will examine the present billing scheme utilized for recovery of DDN costs as well as an alternative usage sensitive billing scheme to satisfy the OSD mandate.

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I. INTRODUCTION

A. PURPOSE

The Defense Data Network (DDN) program plan approved by the Office of the Secretary of Defense (OSD) on 2 April 1982 and subsequent OSD policy guidance on DDN provides for the eventual recovery of applicable network costs by billing of subscribers based upon their utilization of network resources. This thesis will examine the present billing scheme utilized for recovery of DDN costs as well as an alternative usage sensitive billing scheme to satisfy the OSD mandate.

The remainder of Chapter I provides a brief history of the origination of DDN and some background on the network helpful for understanding the information presented throughout this thesis. Chapter II discusses the present funding of DDN through the Communications Services Industrial Fund. Chapter III examines network costs and describes the inherent relationship between network design and network costs. The costing alternative is presented and discussed in Chapter IV. In Chapter V, usage sensitive billing is examined as utilized in commercial communications industry. Also discussed is the effect which user behavior may have on a usage sensitive billing scheme. Finally, conclusions are drawn in Chapter VI.

B. HISTORY

In 1980, AUTODIN II failed to meet its extended Initial Operational Capacity target prompting the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence (C^3I) to order a review of possible alternatives to the AUTODIN II program. In September 1981, lingering doubts regarding technical performance and survivability led the Defense Communications Agency (DCA) to establish two separate design teams to develop (1) the most survivable AUTODIN II system, and (2) an alternative system based on the existing ARPAnet technology. The ARPAnet is the packet-switched data communications network developed by the Defense Advanced Research Projects Agency. Subsequent reviews of the design teams' reports, coupled with a review by a Defense Science Board task force, led to the conclusion that the ARPAnet replica system better fit Department of Defense (DoD) needs for data communications. On April 2, 1982, the AUTODIN II program was terminated and the Deputy Secretary of Defense directed the implementation of the Defense Data Network.

C. BACKGROUND

The Defense Data Network (DDN) is a common user data communications network designed to support critical military operational and intelligence systems as well as general purpose automated data processing (ADP) systems and data

networks having long-haul data communications requirements. Mandated by the Office of the Secretary of Defense, DDN replaced AUTODIN II as the data communications network for the Department of Defense (DoD). Providing a more survivable backbone communications capability than AUTODIN II, "DDN is designed to incorporate the maximum practical modularity and flexibility in the backbone system and its various interfaces to accommodate significant changes in user requirements, in ADP and data communications technology, and in economic factors." [Ref. 1: p. 2] The Under Secretary of Defense for Research and Engineering stated in his Memorandum for the Secretaries of the Military Departments, Directors of Defense Agencies, Director of the Joint Staff and OJCS, dated 10 March 1983, that [Ref. 1: p. 4]:

> All DoD ADP systems and data networks requiring data communications services will be provided long-haul and area communications, interconnectivity, and the capability for interoperability by the DDN. Existing systems, systems being expanded and upgraded, and new ADP systems or data networks will become DDN subscribers.

As stated, the DDN is based on ARPAnet technology. In 1969 the Defense Advanced Research Projects Agency (DARPA) designed a purely experimental network to provide efficient communications to the research and development (R&D) community. In 1975 management of ARPAnet was transferred to the Defense Communications Agency (DCA). The original ARPAnet evolved by 1983 into two separate networks; ARPANET for R&D, and MILNET, the unclassified segment of the DDN.

The concept of DDN is that of a multi-level secure communications network. At the present time there are several operational and planned subnetworks of DDN.

ARPANET	Experimental network
MILNET	Unclassified segment
DISNET	Defense Integrated Secure Network
SACDIN	Strategic Air Command Digital Network
SCINET	Sensitive Compartmented Information Network
WIN	WWMCCS (Worldwide Military Command and Control System) Intercomputer Network

DISNET, SACDIN, SCINET and WIN are to eventually integrate to form the classified segment of DDN. The classified and unclassified segments of DDN will interconnect via one-way switch level network gateways. The final phase in the integration of the subnetworks revolves around a National Security Agency (NSA) device called BLACKER. The BLACKER device will permit the segmented DDN to integrate into a single, shared, multi-level secure network. Figure 1.1 depicts the planned evolution of DDN. Appendix A contains topology maps of existing ARPANET, WIN, and MILNET configurations as well as planned expansions for MILNET Pacific, DISNET, and SCINET.

By the end of 1986, the DDN will consist of 195 packet-switching nodes (PSNs) linked together by 423 access trunks, leased circuits and satellite links. The network topologies, as depicted in Appendix A, are developed based

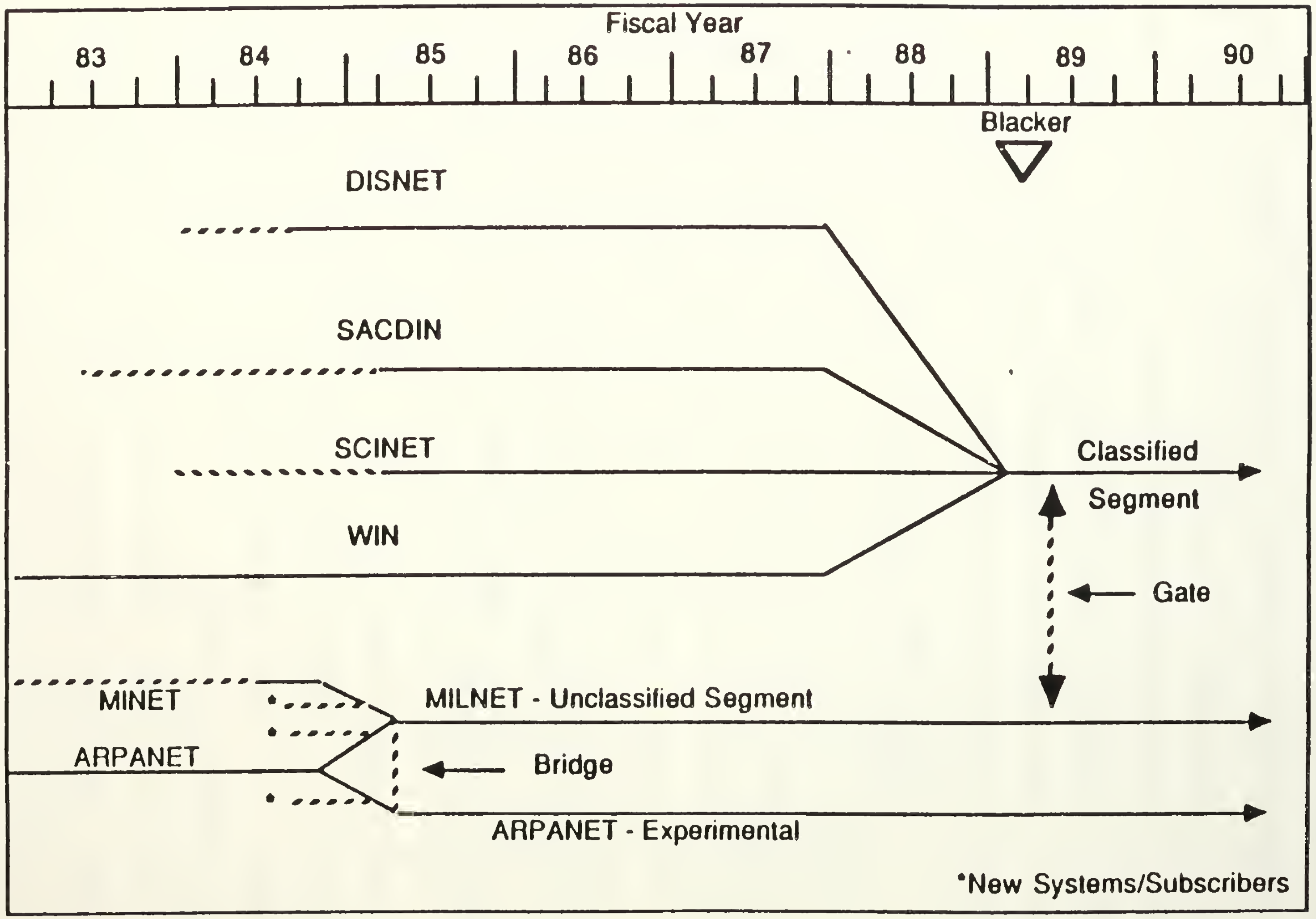


Figure 1.1 Planned Evolution of DDN

on user requirements. Ideally, the user needs only to identify his requirements, acquire the appropriate interface, and submit a request for service. It is not the intent of this thesis to examine individual user implementation on DDN. What this thesis will examine is the current payment scheme for DDN and an alternative to that scheme.

II. FUNDING

A. COMMUNICATIONS SERVICES INDUSTRIAL FUND

DDN is currently funded through the Communications Services Industrial Fund (CSIF), managed by DCA. Before delving into the specifics of the CSIF some information about industrial funds in general is in order. Industrial funds were basically designed to meet the following objectives [Ref. 2: p. 1-1]:

> Provide a more effecitve means for controlling the costs of goods and services required to be produced or furnished by industrial--and commercial--type activities, and a more effective and flexible means for financing, budgeting, and accounting for the costs thereof.
>
> Create and recognize contractual relationships between industrial--and commercial--type activities and those activities that budget for and order the end-products of services, in order to provide management advantages and incentives for efficiency.
>
> Provide to managers of industrial--and commercial--type activities the financial authority and flexibility required to procure and use manpower, material, and other resources effectively.
>
> Encourage more cross-servicing among the DoD components and among their operating agencies, with the aim of obtaining more economical use of facilities.
>
> Facilitate budgeting for and reporting of costs of end-products. This will underline the cost consequences of choosing between alternatives.
>
> To furnish managers of industrial--and commercial--type activities with modern management tools comparable to those utilized by efficient private enterprises engaged in similar types of activites.

To improve cost estimating and cost control by using the constraints of a formal contractual relationship and the requirement for the comparison of estimates and actual costs.

To obtain alert, forward-looking financial planning at industrial-- and commercial--type activities by making them financially dependent on reimbursements received for goods and services furnished in fulfilling orders from customers.

To encourage producers of goods and services to coordinate labor forces and inventories with workload, budgeting, and cost control.

To install in the officials of ordering agencies a greater sense of responsibility and self-restraint in limiting their orders and in balancing the cost of specific goods and services to be ordered against the benefits and advantages of their procurement, especially in the light of alternative or competing demands.

To place ordering agencies in the position of critic of purchase prices as well as quality and delivery speed of goods and services ordered.

To enable ordering agencies to budget and account on an "end-product" basis (the same as when buying from commercial contractors), simplifying budget presentations, budgetary control, and accounting procedures for both producers and ordering agencies.

To establish, whenever feasible, stabilized rates and unit process for goods and services furnished by industrial fund activities, thus enabling ordering agencies to plan and budget more confidently.

To encourage ordering agencies' management to improve program planning and scheduling in response to producers' efforts to plan and negotiate for orders as far in advance as feasible.

As can be seen not all of the objectives apply to communications services and the CSIF; however, a number of them do apply. The Communications Services Industrial Fund Charter specifically authorizes DCA to finance communications services for DoD [Ref. 3: p. 2]:

> Under the management control of the Director, Defense Communications Agency, the purpose of the "Communications Services Activity" is to furnish those communications services, as authorized by the Secretary of Defense, to the Departments and Agencies of the Department of Defense. As directed or authorized by the Director, Defense Communications Agency, or higher authority, the "Communications Services Activity" will also furnish such communications services to other U.S. Government Departments and Agencies or other users as may be appropriate and authorized by law.

The CSIF charter also dictates that authorized users of the communications services will reimburse the fund according to pre-determined subscriber rates, approved by the Assistant Secretary of Defense (Comptroller). The subscriber rates will include operation and maintenance costs for the backbone (switches and trunks) and an applicable portion of the operating costs of the Defense Commercial Communications Office (DECCO). [Ref. 3: p. 2]

Development, acquisition, implementation, operation and maintenance costs for DDN are currently shared by DCA, government agencies, and the Military Departments (MILDEPs). Pre-established CSIF monthly billing rates are paid by the MILDEPs and agencies. The original planning rates were based on a percentage of the initial requirements identified for each agency or department. The billing rates for fiscal year 1985 and planning rates for fiscal years

1986-1991 are depicted in Figure 2.1. [Ref. 4: encl. 4] As can be determined from the rates listed in Figure 2.1, each of the MILDEPs contribute approximately 30.8% of the overall CSIF bill. For fiscal year 1986 the annual bill for leased lines costs for each MILDEP is $16,800,000.00. "While this current charging scheme has been appropriate for the early years of DDN, the growth in subscribers and traffic projected for DDN and the impact of that growth on network costs require that alternative cost recovery mechanisms be evaluated to ensure equitable and efficient cost recovery [Ref. 5: p. 3]." The key word here is equitable. In March 1983, the Under Secretary of Defense for Research and Engineering directed that DCA [Ref. 1: p. 7]:

> ...develop effective cost recovery alternatives for the DDN through the CSIF based on equitable rates reflecting actual system usage to the maximum extent feasible.

In the following sections "actual system usage" will be examined as well as several other parameters which must be considered in the development of an "equitable and efficient" rate structure.

Prepared as of February 1985

DEFENSE DATA NETWORK (DDN) SERVICE
MONTHLY BACKBONE PLANNING RATES
(DOLLARS IN THOUSANDS)

PART I:	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
DEPARTMENT OF THE ARMY	1,000	1,400	1,575	1,775	1,844	1,912	1,980
DEPARTMENT OF THEY NAVY	1,000	1,400	1,575	1,775	1,844	1,912	1,980
DEPARTMENT OF THE AIR FORCE	1,000	1,400	1,575	1,775	1,884	1,912	1,980
DEFENSE COMMUNICATIONS AGENCY	75	122	137	155	161	167	170
DEFENSE LOGISTICS AGENCY	90	122	137	155	161	167	170
DEFENSE INTELLIGENCE AGENCY	45	45	275	310	322	334	340
DEFENSE NUCLEAR AGENCY	6	10	11	12	13	14	14
NATIONAL SECURITY AGENCY	30	50	229	248	257	267	275

— Defense Data Network backbone planning rates continue to be based on a flat monthly rate for the above listed DoD activities, based on their projected usage of the DDN.

PART II: MONTHLY BACKBONE PLANNING RATES FOR ALL OTHER DOD ACTIVITIES
NOT INDICATED IN PART I ABOVE, AND NON-DOD ACTIVITIES
(IN DOLLARS)

	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991
Cost Per Month for Each Occupied IMP Host Port	$ 4,000	$ 4,500	$ 5,000	$ 5,500	$ 6,000	$ 6,500	$ 7,000

Figure 2.1 CSIF Planning Rates

B. WHAT DOES THE CSIF PAY FOR?

What precisely does the CSIF pay for? The principle CSIF costs are [Ref. 6: p. 11]:

- Leased Communication Lines
- CSIF-funded Capital Investments
- System Engineering and Installation
- Systems Operation
- Life Cycle Management
- Network Information Services

The largest cost element for DDN operations is the leased communication lines. "Leased communication lines include the trunk lines that connect network nodes (PSNs) to one another, and the access lines between hosts and node switches, between terminals and terminal access controllers (TACs), and between TACs and node switches [Ref. 6: p. 12]." The number of PSNs, TACs, and interconnecting trunk lines comprise the configuration of the DDN and influence trunk costs.

Recent policy changes permit the acquisition of new equipment by the CSIF as capital investment. The Deputy Secretary of Defense, in his Memorandum for Secretaries of the Military Departments, Chairman of the Joint Chiefs of Staff, Under Secretaries of Defense, Assistant Secretaries of Defense and Directors of the Defense Agencies, dated 9 October 1985, stated [Ref. 7]:

> DoD-owned equipment is currently purchased and financed by the host Military Department on whose installation the equipment resides. This places an unfair financial burden on the Military Departments. It also permits users of the communication system to gain the benefit of this equipment without paying their share of the costs. Financing DoD-owned equipment through the Communications Services Industrial Fund will result in each user of the system paying their relative share of the cost based on the amount of services actually utilized.

DDN capital investments include packet-switching nodes, terminal access controllers, and network access components such as the mini-tac. Improved network services to subscribers can be achieved through such capital investments. "Such equipment could provide users with faster service, improved security, or entirely new network services" [Ref. 6: p. 12].

System engineering and installation costs are not anticipated to be a large portion of network costs. They are, however, included to provide the engineering and installation of new network components in a network configuration that is truly dynamic.

Network monitoring centers provide day-to-day operation of the DDN; performing monitoring, control, and managerial functions. There are currently three regional monitoring centers for MILNET and one for ARPANET:

- MILNET Monitoring Center, Arlington, Virginia
- European Monitoring Center, Vaihingen, Germany
- Pacific Monitoring Center, Wheeler AFB, Hawaii

- Cambridge MILNET Monitoring Center, Cambridge, Massachusetts (ARPANET)

Each monitoring center is responsible for detecting failures and configuration anomolies in the PSNs, the backbone links, and TACs. By continuously checking these components in its portion of the network, each monitoring center signals the operations staff in the event of failure. In addition, the monitoring centers are responsible for coordinating any changes to the PSNs, access devices, or circuits. New software releases may be downline-loaded to the PSNs using the DDN.

"The life cycle management costs represent the second largest component of CSIF costs and include the costs of maintaining all network hardware and software" [Ref. 6: p. 14]. Training services and long-range configuration management are provided by life cycle management.

Network information services are provided by the Network Information Center (NIC). The NIC maintains a collection of network information and serves as a source of general reference material for the network. The following references are available from the NIC:

- The DDN Directory
- The DDN Protocol Handbook
- The DDN New Users Guide
- DDN Newsletter
- DDN Management Bulletin

- DDN News Flash
- DDN Protocol Documents

The NIC also provides on-line network services including:

- NIC/QUERY Program
- WHOIS
- NIC Hostname Server
- TACNEWS
- On-line Files: Internet DoD Hostnames Tables
DDN Host Administrators File
Liaison Files
Request for Comments
Internet Experimental Notes

Finally, the NIC registers New MILNET users by assigning and maintaining TAC access identification and passwords for all dial-in users.

III. <u>COSTS</u>

A. DDN COSTS

DDN costs can be broken down specifically into common costs, user-specific costs, and traffic sensitive costs. The <u>DDN Cost Allocation Model</u> proposes a tariff structure which encompasses these three costs. The DDN tariff structure is designed to [Ref. 6: p. 2]:

- Provide a basis for the comparison and economic evaluation of various approaches to the utilization of the DDN.
- Provide the capability to generate sufficient funds to recover CSIF-funded network costs.
- Distribute these costs equitably among network users based upon their utilization of the DDN.
- Promote efficient, cost-effective use of the network.
- Provide incentives and disincentives designed to reduce users' charges.

The DDN tariff structure allocates DDN costs among users on a balanced and equitable basis. It is "designed to support cost recovery in such a manner that the amount recovered from each subscriber is proportional to the subscriber's usage of network resources" [Ref. 6: p. 7]. In proportioning DDN costs it is necessary to define each of these costs listed above.

1. Common costs can be considered as "overhead". They are the basic costs of providing network services and the costs of making those services available to the user, such costs include Network Monitoring Center operations and maintenance of NIC services. "These costs are largely invariant with the size of the network or the amount of traffic it handles" [Ref. 6: p. 16]. A fixed monthly charge is recommended to recoup common costs.

2. User-specific costs refer to those costs required to provide different types of access for users. There are several categories of user access to DDN:

- Host access
- Dedicated terminal access
- Dial-in terminal access

Each of these levels of access will be discussed more fully in Chapter IV, which examines the tariff structure in more specific terms. It should be noted, however, that a fixed monthly connection charge could be utilized to differentiate between these three user access levels. "While the common costs of the network should be recovered through the monthly connection charge to users, differentials in the monthly connection charge should account for the fact that, independent of traffic passed, it is more expensive to provide service to certain users, given the technical characteristics of the service being provided" [Ref. 6: p. 9].

3. The third element of DDN costs is traffic sensitivity. Traffic-sensitive costs will vary with the number of kilopackets (1000 packets) transmitted by the network. The number of PSNs and internode trunks is proportional to the volume of traffic on the network. "Internode trunks, the largest traffic-related cost, are traffic-related because when the network handles more traffic, more trunks are required to move the traffic within specified performance and delay parameters" [Ref. 6: p. 16].

DDN costs as described above are in essence determined by network design. The relationship between network design and elements of cost is discussed in the following section.

B. NETWORK DESIGN AND COST

DDN costs are clearly related to network design. Network design in turn is determined by the following parameters:

- Network performance requirements
- Network reliability requirements
- Projected network usage.

DDN is designed to instantaneously move data across the network regardless of demand on network resources, i.e., PSNs and trunks. Increased throughput capacity via the addition of trunks and switches is the methodology utilized to achieve this performance objective. As the number of DDN subscribers continues to grow so will the volume of traffic, forcing continued increases in network capacity and,

therefore, higher network costs. Throughput capacity and delay constraints define the necessity for additional network assets, PSNs and trunks. There are four components of delay that each data packet must confront: propagation delay, transmission delay, processing delay, and queuing delay. These components are defined below [Ref. 5: p. 37]:

> Propagation delay is determined by the number of miles a packet has to travel and the physical speed of light.
>
> Transmission delay is determined by the length of a packet and the transmission rate of the trunks the packet must traverse to reach its destination.
>
> Processing delay occurs within the packet-switching nodes themselves and increases with the number of nodes a packet must pass through to arrive at its destination.
>
> Finally, a packet will experience delays as it waits in "queues" for a busy node or trunk to be free.

Network reliability is provided in part by the dynamic routing scheme employed by the DDN. In addition, each node has multiple independent connections to ensure that if any trunk should fail there will always be an alternate path available. "Each of the nodes must have at least two outgoing backbone trunks, ... moreover, these trunks must be configured in such a way that no one trunk would partition the network if it failed"[Ref. 5: p. 37]. Clearly, placement of nodes and trunks is required to meet reliability requirements as well as traffic requirements.

Network usage is a final factor in the determination of network cost. There are five general characteristics to be considered in reviewing network usage: (1) quantity, (2) time of day, (3) geographical distribution, (4) duration, and (5) type of service.

As DDN is a packet-switching network, user data is grouped into "packets" for transmission. User data inputs called messages are broken down into packets, packets are sent out over the network with a specified quantity of overhead data to ensure proper delivery to the destination node. Reducing the amount of overhead data relative to user data can reduce the volume of traffic, i.e., quantity of packets, on the network. Specifically [Ref. 5: p. 10]:

> A single DDN packet can hold 1008 bits of user data. The DDN packet switched append 200 bits of network control overhead data to each of these packets. Subscriber hosts present data to the network in units called messages which are in turn divided into packets by the DDN switches. The size of the data field in each message can significantly affect network efficiency. At one extreme a subscriber application may place only a single byte (8 bits) of data in each message. In this case the network will have 200 bits of subnet overhead for every 8 bits of data. This means that network trunks will be 96% loaded with subnet overhead (200/208). On the other hand, an application which can send messages which are an integral number of packets long will lower the overhead percentage to 17 percent (200/1208).

As can be seen, network efficiency can be drastically improved as packet length increases.

During normal business hours traffic volume on the network is over four times higher than it is in the middle of the night. Figure 3.1 is a graphic representation of this [Ref. 5: p. 13]. "Since the network must be designed to meet the peak hour requirement, the more a subscriber requires heavy network usage during the peak hour, the more he contributes directly to the cost of provisioning the network" [Ref. 5: p. 12]. Subscribers should be encouraged to shift heavy usage whenever possible to the off-peak hours.

Geographic distribution pertains to the distance subscriber data must travel and the number of nodes it must traverse. Basically, DDN trunk lines are, for the most part, leased from commercial companies which provide service based on a distance sensitive tariff. The mileage component of the commercial tariff can therefore be directly related to the distance over which a DDN packet must travel. A further point to be considered in the discussion of geographic distribution is that of centralization versus decentralization of subscriber application. A centralized application may provide a greater economy of scale for

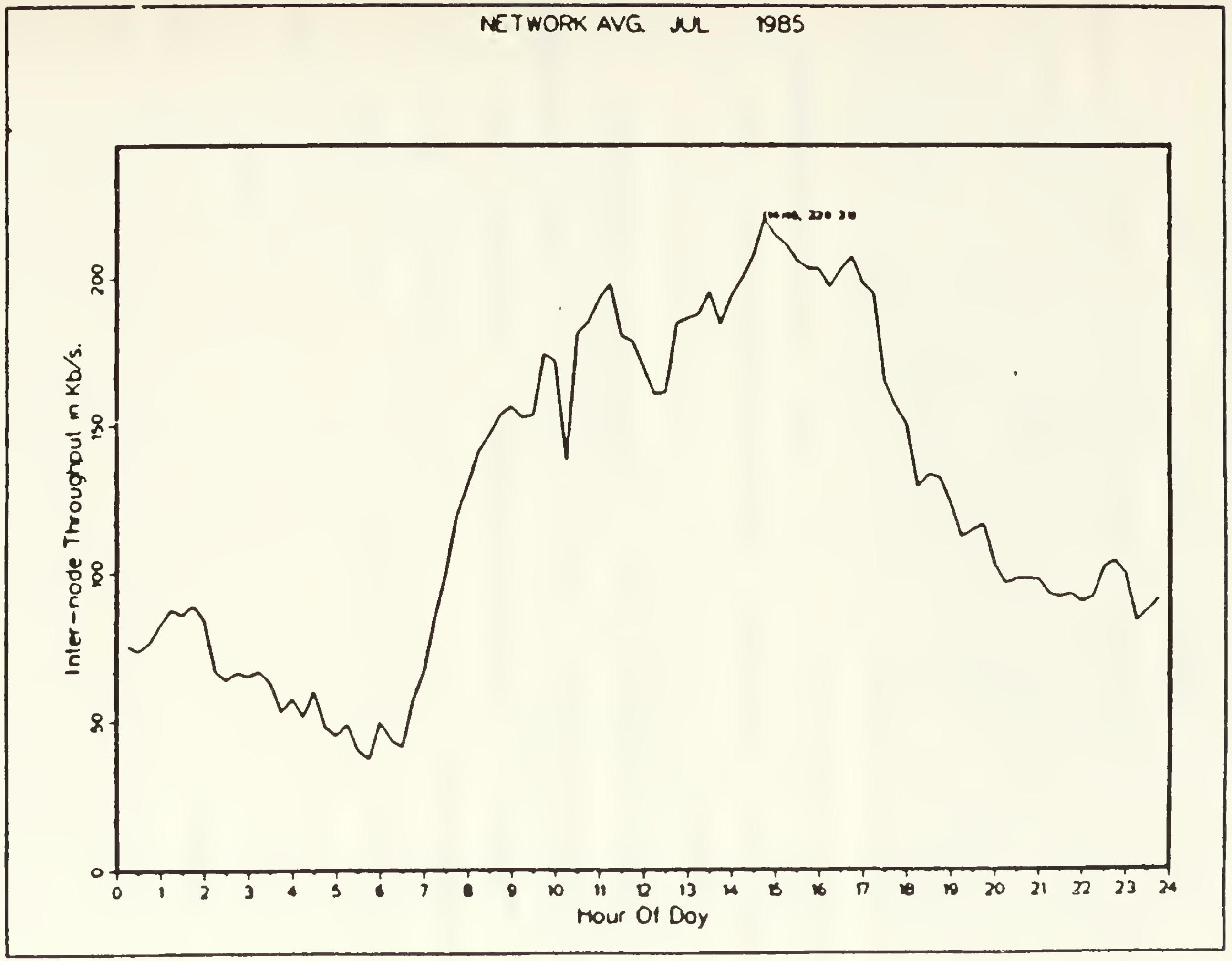


Figure 3.1 Distribution of MILNET Traffic

computing power but require more and longer data access lines. Finally, there is the issue of network ports. Each DDN port activated incurs hardware and operations management costs in addition to a circuit charge for remote access when required [Ref. 5: p. 15]:

> Presently, most subscriber devices attach directly to a DDN interface device (switch or access controller). In the future more and more subscribers will be employing local data distribution systems such as LANs (local area networks) and PBXs (private branch exchanges). These systems offer the possibility for decreasing the number of DDN ports needed to service a subscriber requirement through the use of a few gateway ports which can service all subscriber devices on the local distribution system.

Duration becomes an important factor when considering dial-in terminal users. Both duration and type of service will be discussed in Chapter IV.

In summary, in many cases the important components of network usage will be quantity as it pertains to average packet length and time of day profiles. However, total quantity, duration, and type of service need also be considered but to a lesser extent.

IV. A COSTING ALTERNATIVE

As stated in Chapter II, current DDN costs are paid through the CSIF by the MILDEPs and those government agencies that use the DDN. These costs are shared among these agencies. "The present user billing system, in which telecommunications services are paid for by centralized organizations in each component, is highly counter-productive and leads to serious degradation in services" [Ref. 8: p. 9].

AUTOVON, the DoD common user long distance service, can serve as an example for DDN. AUTOVON is available to most DoD users and is paid for by the centralized communications organizations. It is viewed by many individual users as a "free" service in that they never see the bill and are never called to account for their usage. Service is adversely affected by the indiscriminate abuse of the AUTOVON system. A rate structure which broke down AUTOVON costs to the individual user at command level could help eliminate much of the abuse and improve service radically. "It is a simple proposition of economic theory that rate structures largely invariant with intensity of use or time of day will not yield efficient utilization of capacity in systems characterized by such variations" [Ref. 9: p. 83]. The DDN Cost Allocation Model puts forth a provisional tariff which encompasses both factors mentioned above.

A. TARIFF

John R. Meyer, in his book The Economics of Competition in the Telecommunications Industry, puts forth eight basic goals of regulatory rates [Ref. 9: p. 102]:

(1) Universal service
(2) Static efficiency in resource allocation
(3) Equality for different kinds of users and service
(4) Financial self-sufficiency (total revenues equal to total cost)
(5) Prevention of uneconomic entry
(6) Consistency with expected technological change
(7) Administrative simplicity
(8) Historical continuity

The DDN provisional tariff attempts to achieve a number of these goals.

The DDN provisional tariff, hereafter known as the tariff, consists of two parts [Ref. 6: p. 17]:

A basic monthly connection charge consisting of a basic charge and any applicable user-specific surcharges, and

A traffic charge based upon the number of packets sent over the network each month.

Common network costs are allocated among subscribers, with the exception of dial-in users, regardless of the type of service or volume of traffic generated. The basic monthly connection charge is designed to recover these common costs. "The revenues generated by these charges are to recover the costs of operating and maintaining all network services and facilities allocated as common costs" [Ref. 6: p. 19].

In addition to common costs recovered in the monthly connection charge, a user-specific differential surcharge is

included as well. "Differential surcharges provide a particularly effective means of achieving allocative efficiency since they recover the costs of providing different types of services from the users who benefit from those services " [Ref. 6: p. 19]. There are three types of service for DDN users: host service, dedicated terminal service, and dial-in service.

"There will be a monthly connection charge to cover all support and services associated with host access. The basic subscription charge will apply to all hosts, irrespective of location " [Ref. 6: p. 23]. Premium service options available to hosts include dual-homing and precedence capability. Hosts can obtain these services at a cost over and above the basic monthly host connection charge. Subscribers may also require wide-band access lines for host access. There will be a higher charge for wide-band access than for voice-grade. Voice-grade access is at a line speed less than or equal to 9.6 Kbps (kilobits per second); wide-band, greater than 9.6 Kbps.

Dedicated terminals will have a basic monthly connection charge derived from the basic host charge and related access costs. A Terminal Access Controller (TAC) is viewed by the network as a host, thus the same common host costs will be allocated to each TAC [Ref. 5: p. 23]:

> The conversion of TAC costs to dedicated terminal costs is through the number of dedicated terminals per TAC on an overall network-wide basis. The basic connection charge for dedicated terminals also includes a component to recover the costs of maintaining the TACs and providing access between the subscriber's terminal and the TAC.

The dedicated terminal charge will be uniform across the network.

There is no monthly connection charge for dial-in users; however, an hourly connection charge is used to recover these charges. In order for a dial-in user to access the DDN, a user identification code must be assigned by the NIC. User IDs are charged against Program Designator Codes (PDCs) for accounting purposes. "Dial-in usage implies that a TAC port is being occupied, and its cost is recovered by a charge for the number of minutes the user is logged in to the network and for the amount of traffic the user generates" [Ref. 6: p. 26]. This charge is passed on the user via user ID and PDC.

Dual-homing is a premium service option available to hosts only. Dual-homing provides complete redundancy of access between a host and the network. The cost of the second access line will be recovered by a monthly surcharge, as will the second PSN port and maintenance cost of the system software that does the rehoming in the event of necessity.

Precedence is another premium service option available to both hosts and dedicated terminals. At the present time

there are two levels of precedence, a user either has precedence capability or does not. Four levels of precedence are planned for DDN; level 1 for routine usage and level 4 for high priority usage. Once again a surcharge would be charged for this option. Precedence capability is equipment specific. In other words, the surcharge is levied against the subscriber's equipment and is charged even if no precedence traffic is transmitted. The surcharge is for the capability to transmit precedence traffic. There will be a separate traffic charge for precedence traffic [Ref. 6: p. 30].

> The special higher charge for precedence traffic is designed in part to serve as a disincentive to use precedence for routine network transactions. The priority traffic charge is over and above monthly equipment access charges for precedence. ... The traffic charge reduces the potential for abuse and also equitably recovers the marginal costs of network resources required for precedence traffic.

Even though all four levels of precedence and preemption capabilities have been included in the DDN, it is doubtful that levels 2 through 4 will be required. Substantial reserve capacity is built into the DDN. "Even during peak daytime traffic, a user will see little difference in performance between level 1 and level 4" [Ref. 4: p. 25].

The differential surcharge for specific user service type, along with the monthly connection charges and charges for premium service options strive to achieve "allocative efficiency." As stated in the DDN Cost Allocation Model [Ref. 6: p. 6]:

> Allocative efficiency requires that the tariff structure applicable to any user should reflect the resources used to provide service to the user. It implies that the tariff should neither subsidize nor discriminate against any group of users.

The final component of the tariff is traffic. Data is sent across the network in the form of packets. Along with equipment access and user connection charges is a per-kilopacket charge. "By charging for traffic on a per-kilopacket basis, the tariff provides a mechanism through which network capacity can fulfill network demand" [Ref. 6: p. 20]. As seen earlier in Figure 3.1, there is a definite peak usage period for DDN. A standard per-kilopacket rate is applied to routine traffic transmitted during peak hours. Previous studies have indicated that, "in situations where the same physical plant can be used to produce a service in different time periods and where the demand characteristics differ in these time periods, prices generally should not be the same at different times of day" [Ref. 9: p. 90]. An off-peak discount rate for routine traffic is incorporated into the tariff. Subscribers with large bulk transactions of time insensitive data can benefit from off-peak discount rates. By using off-peak transmissions and appropriate precedence levels, subscribers can influence their traffic charges. In addition as noted earlier, packet size itself can influence traffic charges [Ref. 6: p. 20]:

Applications on DDN can be designed to carry data in large access packets that effectively reduce a user's traffic charges. Thus, the user and the host software can have an extremely critical role in the cost-effective use of DDN.

In summary, subscriber tariff charges will be an accumulation of connection and traffic charges determined by [Ref. 6: p. 21]:

(a) numbers and types of subscriber equipment
(b) subscriber equipment surcharges
(c) dial-in connection time
(d) kilopackets of traffic generated by a host, dedicated terminal, or dial-in user
(e) traffic surcharges and discounts.

These determinants are illustrated in Figure 4.1.

Along with meeting the goal of allocative efficiency, several other of Meyers' goals of regulatory rates are met by the DDN provisional tariff. The DDN offers universal service regardless of the type of user equipment or location. The tariff also achieves equity among the different types of users and services. To achieve financial self-sufficiency, "the tariff structure must support generation of revenues at least equal to the annual CSIF-funded costs of the network" [Ref. 6: p. 6].

Monthly Equipment Access Connection Charges

Type of Service	Hosts	Dedicated Terminals
Basic Connection Charge	X	X
Access Line Surcharge:		
- Hosts 9.6 Kbps	X	—
- Dedicated term 1.2 Kbps	—	X
Premium Service Surcharge:		
- Dual Homing	X	N/A
- Precedence		
Level 1	No Charge	No Charge
Level 2	X	X
Level 3	X	X
Level 4	X	X

User Connection Charges

Type of Charge	Type of Terminal User	
	Dedicated	Dial-In
Connection Charge per Minute		
- Peak	No Charge	X
- Off-Peak	No Charge	X

Traffic Charges — per Kilopacket

Type of Packet	Host	Dedicated Terminals	Dial-In Users
Precedence Level 1			
- Peak	X	X	X
- Off-Peak	X	X	X
Precedence Level 2*	X	X	N/A
Precedence Level 3*	X	X	N/A
Precedence Level 4*	X	X	N/A

*Irrespective of time-of-day

Figure 4.1 Summary of DDN Tariff Structure

V. USAGE SENSITIVE BILLING

There are four basic objectives to a usage sensitive billing scheme. They are as follows [Ref. 10: p. 67]:

1. To induce subscribers to choose the number of access lines and precedence that best suits their traffic requirements.

2. To provide incentives for efficient use of the system.

3. To allocate the costs of the system to the agencies that use it; the billing should also provide information that will permit agencies, if they wish, to shift the costs to or impose controls or regulations on the individuals or agency subdivisions doing the calling (in our case, using the network).

4. To provide reliable information to the supplier of the service upon which to base decisions about how much capacity is required.

The DDN provisional tariff meets these objectives for the most part. Incentives for efficient use of resources are achieved through the per-kilopacket charges for traffic and the differential surcharges and discounts for premium service options and off-peak transmissions. The traffic charges also supply DCA with an accurate accountability of network usage on which to base capacity decisions. Surcharges based on access line capacity, i.e., voice grade or wideband, also serve to encourage selection of sufficient but not excess access. All indications are that usage billing information will be of such a format as to allow agencies to "bill down" to the actual user level. However, "although DDN will soon provide accounting for the

individual user's service, it will be of little value if the components continue with centralized billing"[Ref. 8: p. 10]. Furthermore, agencies are encouraged [Ref. 8: p. 10]:"to pass user billing charges directly to the using organization, thus optimizing their use of this resource. Failure to do so will seriously downgrade the quality of service available on the DDN."

The final objective to provide reliable information for decision making may be met as far as planning for required capacity is concerned, what might be more helpful, however, is planning guidance for budgetary purposes. Estimates of actual usage costs, and hence traffic charges, will be extremely difficult to predict.

A. COMMERCIAL INDUSTRY

While billing by usage is an innovative billing scheme for the Department of Defense, it is by no means a unique technology. Commercial communications industry has set an example for billing by usage. Several specific examples are provided below.

The GTE Telenet Public Network consists of high-speed transmission facilities interconnected by switching centers. The total monthly rate charge is a composite of 1) usage, 2) network access arrangements, and 3) network interface equipment. The usage component is based on per-kilopacket rates within the United States and a number of international

locations. A connection charge is levied for dial-in service based on an initial two minute charge with an additional charge for each minute thereafter. There is no charge for the first 1.2 kilopackets of traffic transmitted, but an overflow rate is charged for subsequent packets. A monthly leased line cost for dedicated service includes the associated modems (modulator/demodulator), a dedicated port and service on the dedicated line and modems. Network interface is provided by an intelligent data communications processor which serves as either a host computer interface or a terminal interface. Telenet also incorporates a 50% discount rate for service during off-peak evening hours, on weekends and five major holidays.[Ref. 11]

Another example of commercial communications billing by usage is Tymnet, Incorporated. Tymnet is a data communications service utilizing "intelligent concentrators" to effect connections between remote stations and users' facilities. Access to Tymnet is through public telephone networks or customer dedicated access lines. Again, the total monthly access charge is a combination of usage, network access arrangement and interface equipment. Tymnet bills for different types of usage by several methods. Dial-in access is available on a connection charge per connect hour for cumulative hours per month. Dedicated access is a monthly per port charge. A monthly charge is also levied for host connection to Tymnet. Network

connections are available at varying line speeds between the users' premises and a Tymnet Service Office. Customer rates include maintenance, modems and leased lines of fifty miles. A mileage surcharge is levied for access lines of greater than fifty miles. Miscellaneous services offered by Tymnet include [Ref. 11]:

Customer Account Charge: detail of customer and authorized user charges

Network Status Report

Off-peak Usage Discount Rates

A third example of billing by usage is American Telephone and Telegraph Information Services' (ATTIS) Accunet. Offering more limited services than Telenet and Tymnet, Accunet charges a flat monthly connection charge based on line speed with an additional per-kilopacket charge. Accunet's rates are distance insensitive incorporating discounts for time of day and greater traffic volumes. [Ref. 12: p. 68]

As can be seen, usage sensitive billing in all three of the above examples has many similarities with the DDN provisional tariff. The basic monthly connection charge is a common component in all cases as is some sort of traffic charge. Each of the examples, including the provisional tariff, incorporates specifically designed user options for which surcharges are levied. While the billing schemes are all similar, the DDN provisional tariff faces one obstacle not seen by the commercial tariffs. The commercial tariffs

are based on monetary rewards, i.e., discounts, on a more personal level than the DDN tariff. As has been discussed earlier in this thesis, present billing through the CSIF is to the major telecommunications component of the department or agency, for example to Commander, Naval Telecommunications Command (COMNAVTELCOM) for the Navy. If COMNAVTELCOM continues to plan, program and budget for the entire Navy portion of DDN costs, individual users and user commands throughout the Navy cannot be expected to restrict their usage of a capability upon which there is no apparent restriction. The example presented earlier of the AUTOVON system applies. Even if DDN costs are broken down to the user commands, it is doubtful that each individual who uses DDN will be aware of the costs of his usage [Ref. 5: p. 20]:

> The imposition of a usage-based cost recovery system would not require payment by individuals directly out of their personal funds. There is no element of direct and immediate personal reward for using network resources more efficiently.

What can be done to influence user behavior with regard to such an unrestricted resource?

B. USER BEHAVIOR

Prior to discussing individual user behavior and how it can be influenced, some discussion of the user community as a whole must be undertaken. The user community for DDN consists for the most part of the Department of Defense (DoD). Using Anthony Downs' definition from <u>Inside</u>

Bureaucracy, DoD is in fact a bureaucracy. Downs defines an organization as a bureaucracy if the following characteristics are exhibited [Ref. 13: p. 24]:

1. It is large. Generally, any organization in which the highest-ranking members know less than half of all the other members can be considered large.

2. A majority of its members are full-time workers who depend upon their employment in the organization for most of their income.

3. The initial hiring of personnel, their promotion within the bureau, and their retention therein are based at least partly on some type of assessment of the way in which they have performed.

4. The major portion of its output is not directly or indirectly evaluated in any markets external to the organization.

DoD certainly exhibits these characteristics.

Downs has further developed a number of "laws" concerning bureaucracies. These sixteen laws are summarized below. A brief examination indicates that most of them are applicable to DoD and several are specifically applicable to the problem of user billing of DDN.

Below are listed The Laws [Ref. 13: p. 262]:

Law of Increasing Conservatism. All organizations tend to become more conservative as they become older, unless they experience periods of very rapid growth or internal turnover.

Law of Hierarchy. Coordination of large-scale activities without markets requires a hierarchical authority structure.

Law of Increasing Conserverism. In every bureau, there is an inherent pressure upon the vast majority of officials to become conservers in the long run.

Law of Imperfect Control. No one can fully control the behavior of a large organization.

Law of Diminishing Control. The larger an organization becomes, the weaker is the control over its actions exercised by those at the top.

Law of Decreasing Coordination. The larger any organization becomes, the poorer is the coordination among its actions.

Power Shift Law. Unrestrained conflict shifts power upward.

Law of Control Duplication. Any attempt to control one large organization tends to generate another.

Law of Ever Expanding Control. The quantity and detail of reporting required by monitoring bureaus tends to rise steadily over time, regardless of the amount or nature of the activity being monitored.

Law of Counter Control. The greater the effort made by a sovereign or top-level official to control the behavior of subordinate officials, the greater the efforts made by those subordinates to evade or counteract such control.

Law of Free Goods. Requests for free services always rise to meet the capacity of the producing agency.

Law of Non-Money Pricing. Organizations that cannot charge money for their services must develop nonmonetary costs to impose on their clients as a means of rationing their outputs.

Law of Progress Through Imperialism. The desire to aggrandize breeds innovation.

Law of Self-Serving Loyalty. All officials exhibit relatively strong loyalty to the organization controlling their job security and promotion.

Law of Interorganizational Conflict. Every large organization is in partial conflict with every other social agent it deals with.

Law of Countervailing Goal Pressures. The need for variety and innovation creates a strain toward greater goal diversity in every organization, but the need for control and coordination creates a strain toward greater goal consensus.

In particular, the Law of Hierarchy, coordination of large-scale activities without markets requires a hierarchical authority structure; the Law of Imperfect Control, no one can fully control the behavior of a large organization; and the Law of Non-Money Pricing, organizations that cannot charge money for their services must develop nonmonetary costs to impose on their clients as a means of rationing their outputs, apply.

In order for the authority structure within DoD to attempt to manage the vast resource known as DDN, a model of user behavior must be developed. Indeed, "in order to evaluate the effect of usage-based cost recovery on DDN resource utilization, a non-market model of user behavior, not requiring reliance on monetary rewards to the individual user, must be used" [Ref. 5: p. 21]. The following questions must be answered by any non-market behavior model for DDN subscribers [Ref. 5: p. 23]:

- What can be done to affect usage?
- Who can do it?
- When can or must it be done?
- Why would someone do it?

A resource allocation decision model has been developed in response to these questions. The mathematical derivation of the decision model is presented in Appendix B [Ref. 10: p. A-3]. To summarize the resource allocation decision model [Ref. 5: pp. 28-30]:

There are five principles embodied in the resource allocation model.

1. Decisions to undertake specific actions to affect network usage occur at different points in a subscriber system's life cycle.

2. There is always one level of authority which has primary responsibility for a decision to take any given action to affect usage.

3. The level of authority at which decisions are normally made is higher at the earlier the stage of the life cycle of the system,
   i.e., design specifications
   transition plans
   day-to-day operations

4. Potential savings are higher, the earlier the stage of the life cycle of the system.

5. The level of actual savings increases as the level of potential savings increases.

A final observation regarding telecommunications costs is that actual savings will be greater relative to the level of authority at which the decision is made [Ref. 5: p. 33]:

The higher the level of authority at which the decision is normally made.

The earlier in the stage of the life cycle of the system the decision is normally made.

The greater the involvement of officials at higher levels than that at which the decision is normally made (i.e., the greater the intervention of higher officials, other things being equal, the greater the savings.

The truth of these observations can be seen in the need to identify potential savings early in the development and system design phase, where higher ranking officials are more likely to be involved. It is at this stage that decisions as to the most efficient use of DDN for each system may most effectively be made.

VI. CONCLUSIONS

There are a number of conclusions to be drawn from the information researched and presented in this thesis. Several will be discussed in this final section.

The affects of consideration of DDN in the early planning stages of system design and upgrade are stressed throughout. Indeed, studies indicate that [Ref. 14]:

> Cost analysis of proposed DDN subscriber systems support the thesis that the use of DDN solely as a replacement of dedicated data circuits is neither in the best interests of the user nor the network. Rather, the implementation of user practices and procedures together with user system design options...which optimize usage of the DDN will provide a higher degree of service at minimum cost.

Usage sensitive billing strives to contribute to the implementation of users procedures to obtain optimum efficiency of network resource usage. The usage sensitive billing scheme presented in this thesis further attempts to force the responsibility for efficient network usage onto the individual user system through use of additional surcharges for premium service options and discounts for specific usage patterns.

Another conclusion which may be drawn is that to be most effective, a usage sensitive billing scheme should accommodate billing to the lowest practicable level within

each user organization. As presented throughout this thesis legitimate objectives of usage sensitive billing as a method of DDN cost recovery include:

- Provision of the capability to generate sufficient funds to recover CSIF funded network costs.
- Distribution of network costs equitably among network users based upon actual utilization of network resources.
- Reduction in network costs through promotion of efficient, cost-effective use of the network.
- Provisions of cost incentives and disincentives to the user for optimum utilization of network resources.

The first objective can be achieved without regard to the organizational level within each DoD component at which the budgeting and funding responsibility resides. However, in order to realize the final three objectives, this responsibility must be fixed as close to the using activity as possible. Precisely how this will be accomplished remains to be seen.

A final conclusion which will be drawn here is that early involvement of high level officials will yield significant savings. Chapter V discusses this factor thoroughly. However, one point to consider is that high level officials may be more likely to be held accountable for spending practices. It is more to the direct advantage of a commanding officer, for example, to realize a cost savings than it is to a junior officer on the staff. Therefore, higher level officials will express greater

interest in potential saving schemes. Thus to involve those individuals in the design of systems will only increase the actual savings realized in a usage billing environment.

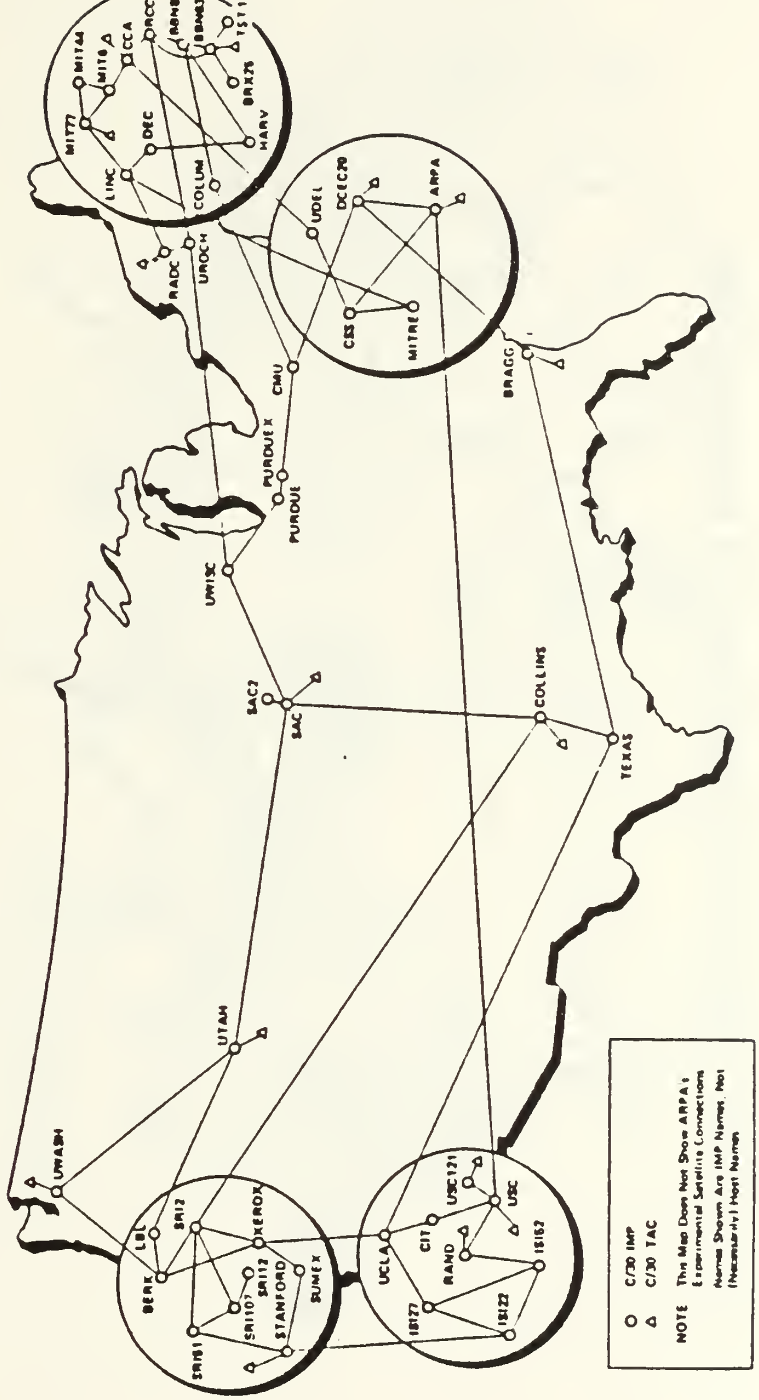
Reference 6, DDN Cost Allocation Model, can be used to develop a user billing rate. "However, it has been considered that due to the lack of usage data, the subscriber community is not yet ready to program and budget for DDN costs based upon usage sensitive rates" [Ref. 14].

> The capability has been developed to collect and process MILNET usage data for distribution to interested organizations in support of management and planning actions and of projections of future subscriber costs in the usage sensitive environment. Initial distribution of 1986 data is expected in April 1986. [Ref. 14]

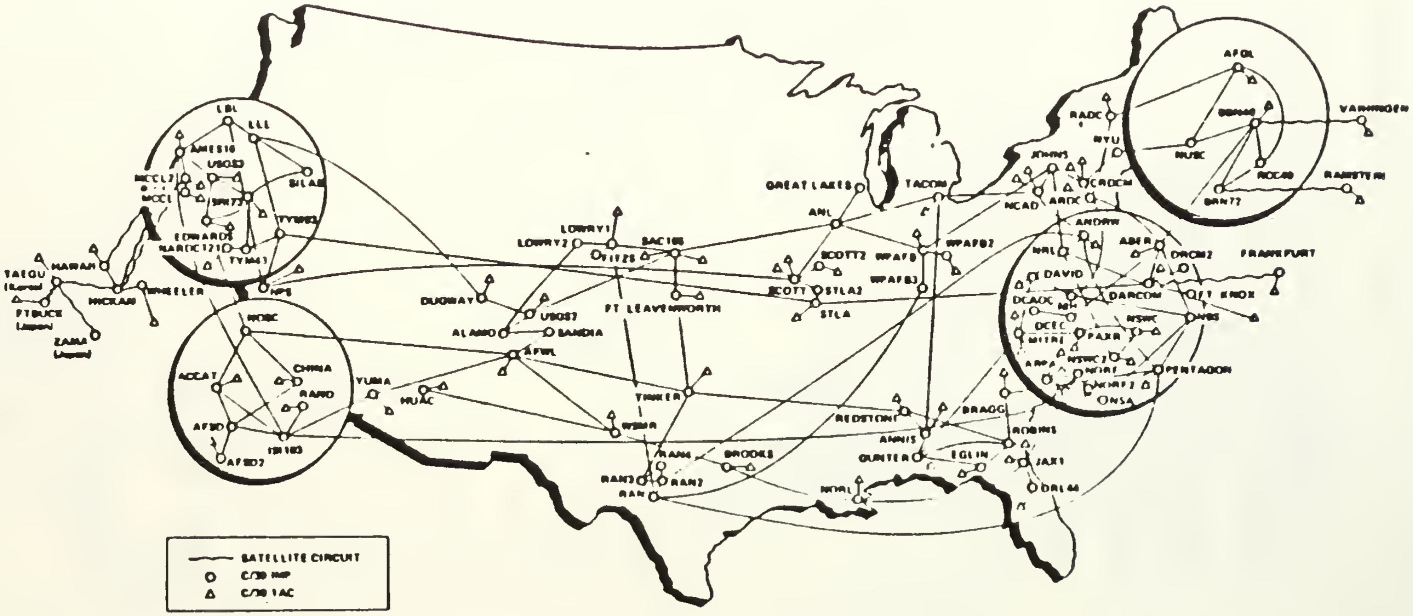
It is anticipated that this usage data will provide much needed planning data and that future reports of usage information will assist in the formulation of usage trends which may be used to project and forecast subscriber usage. Such forecasts may in turn provide users with the required backbone information necessary for budgetary and programmatic planning. In addition, usage data may permit analysis of individual subscriber usage patterns and promote the efficiency thereof. Detailed analysis may provide insight into the most effective and efficient systems design on DDN.

APPENDIX A
DDN TOPOLOGY

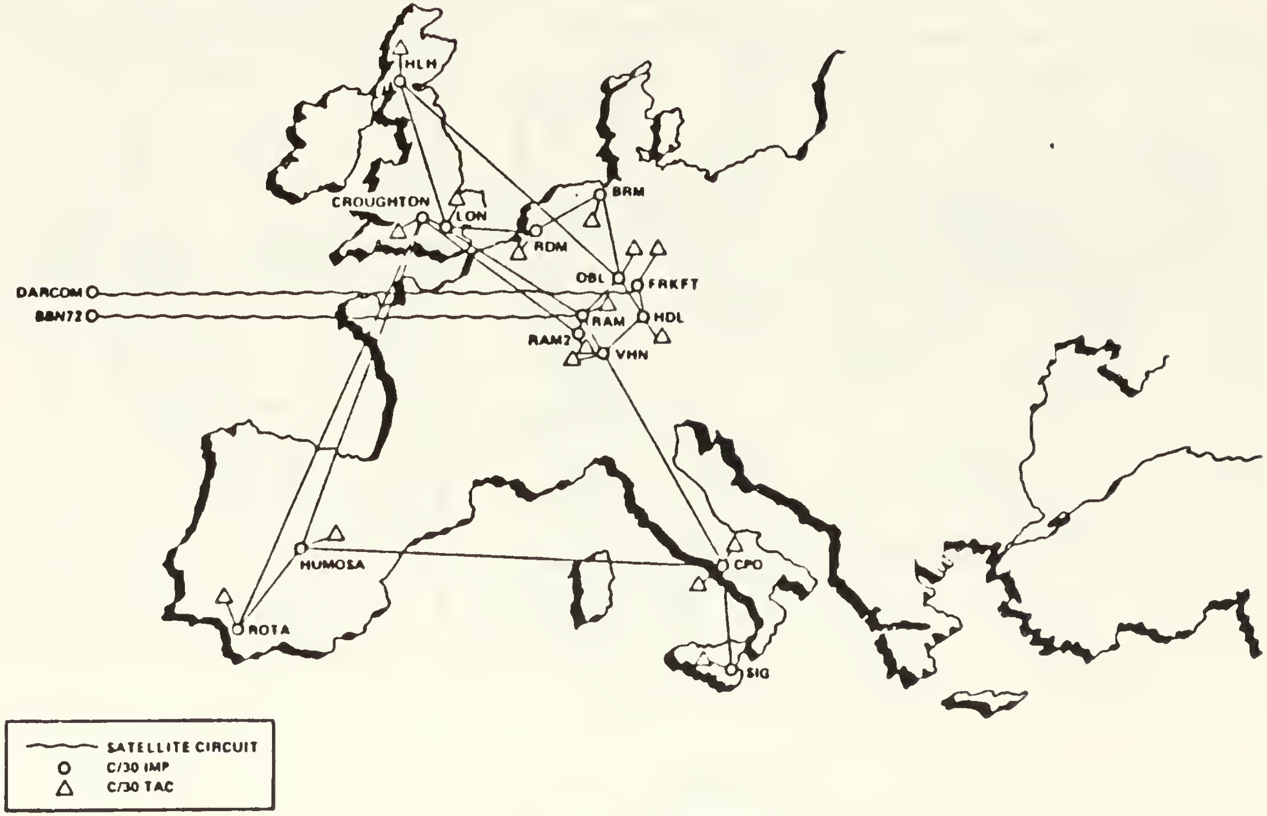
ARPANET Geographic Map, 31 December 1985



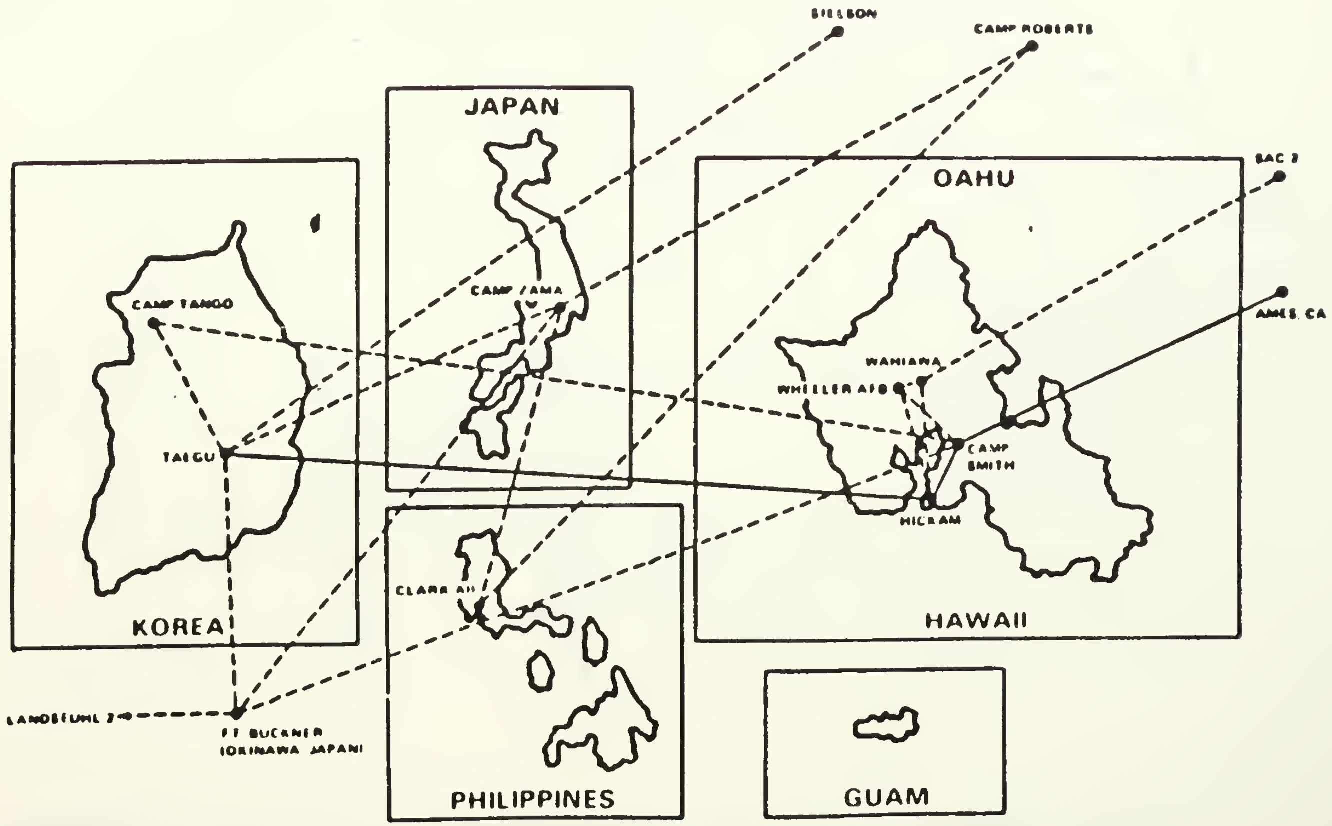
MILNET Geographic Map, 31 December 1985



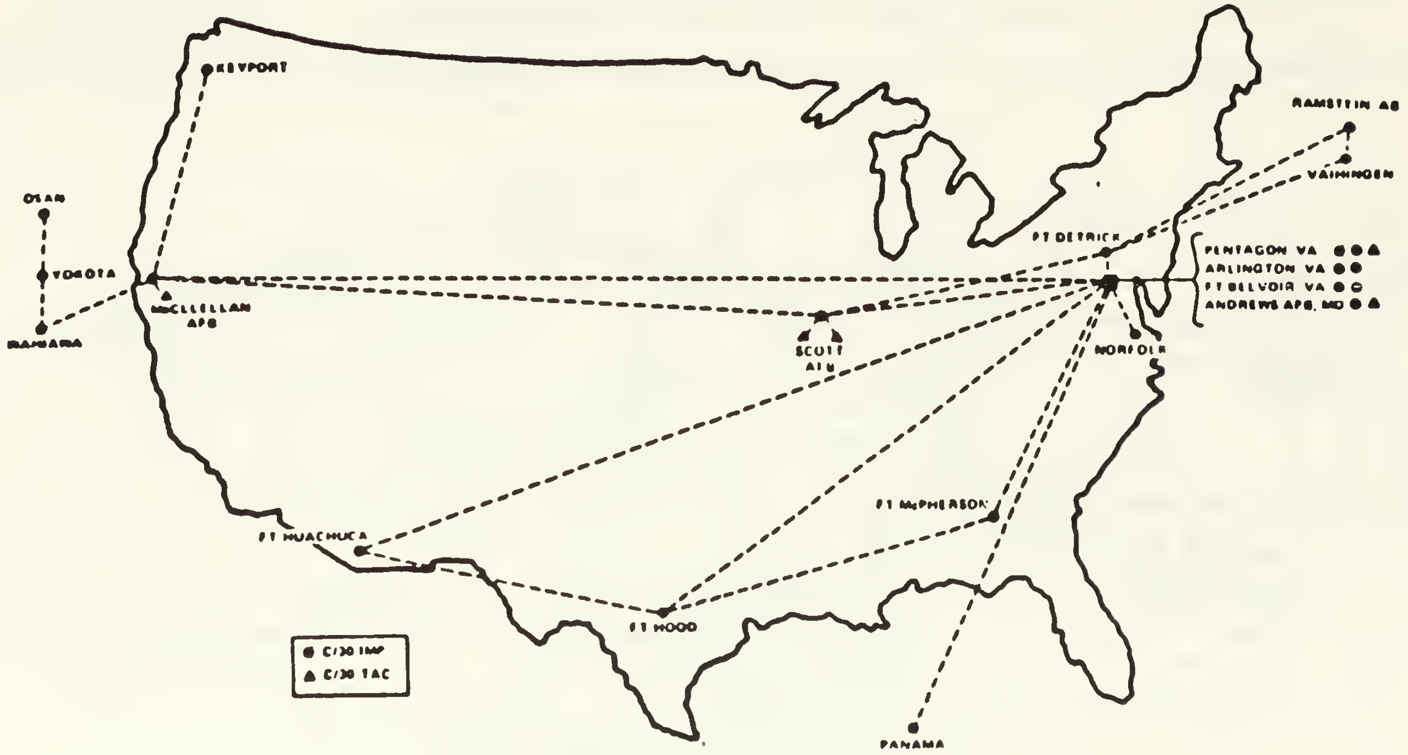
European MILNET Geographic Map, 31 December 1985



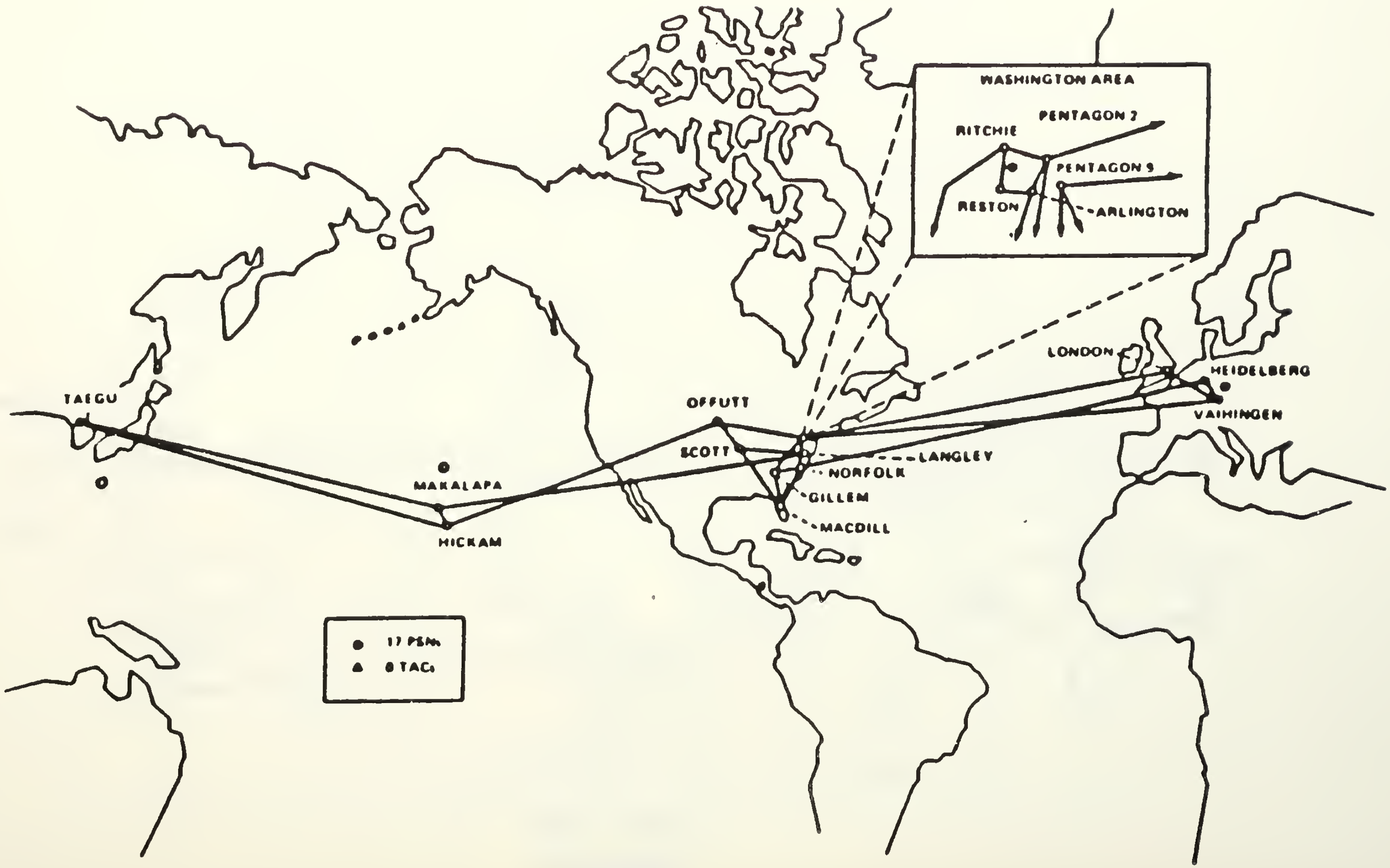
MILNET PACIFIC
(85—86)



DISNET
(85—86/87)



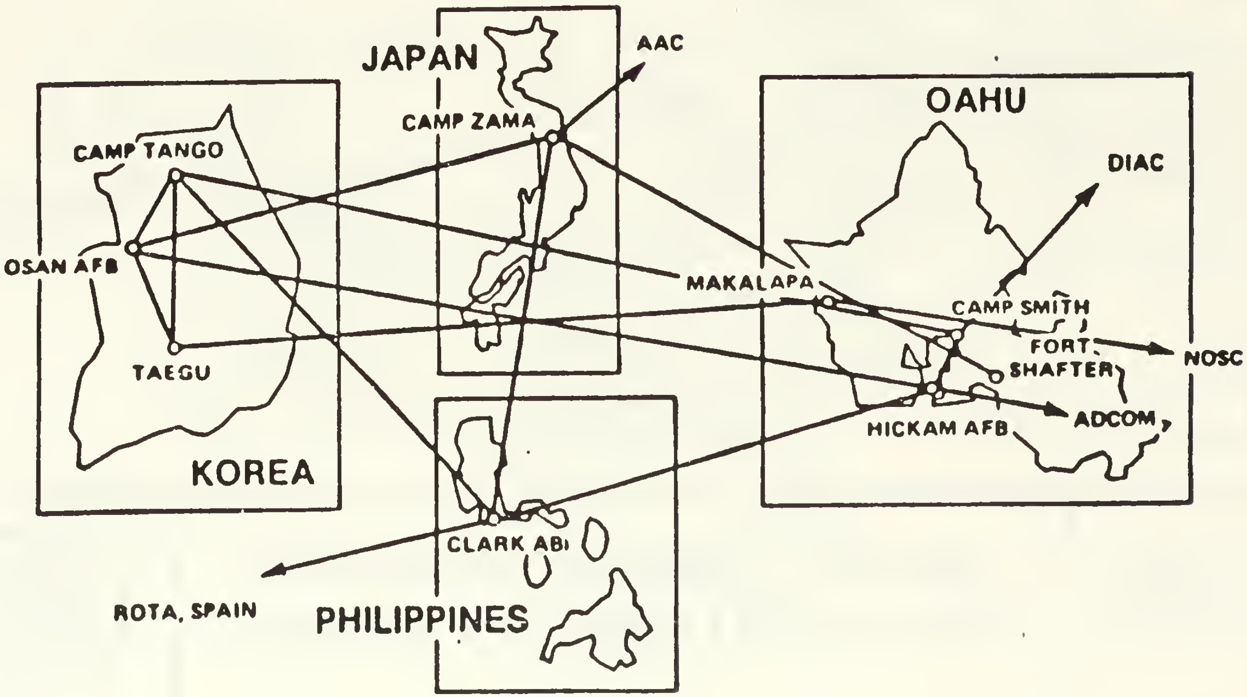
WIN COMMUNICATION SUBSYSTEM



SCINET FUTURE TOPOLOGY

PROPOSED PACIFIC THEATER

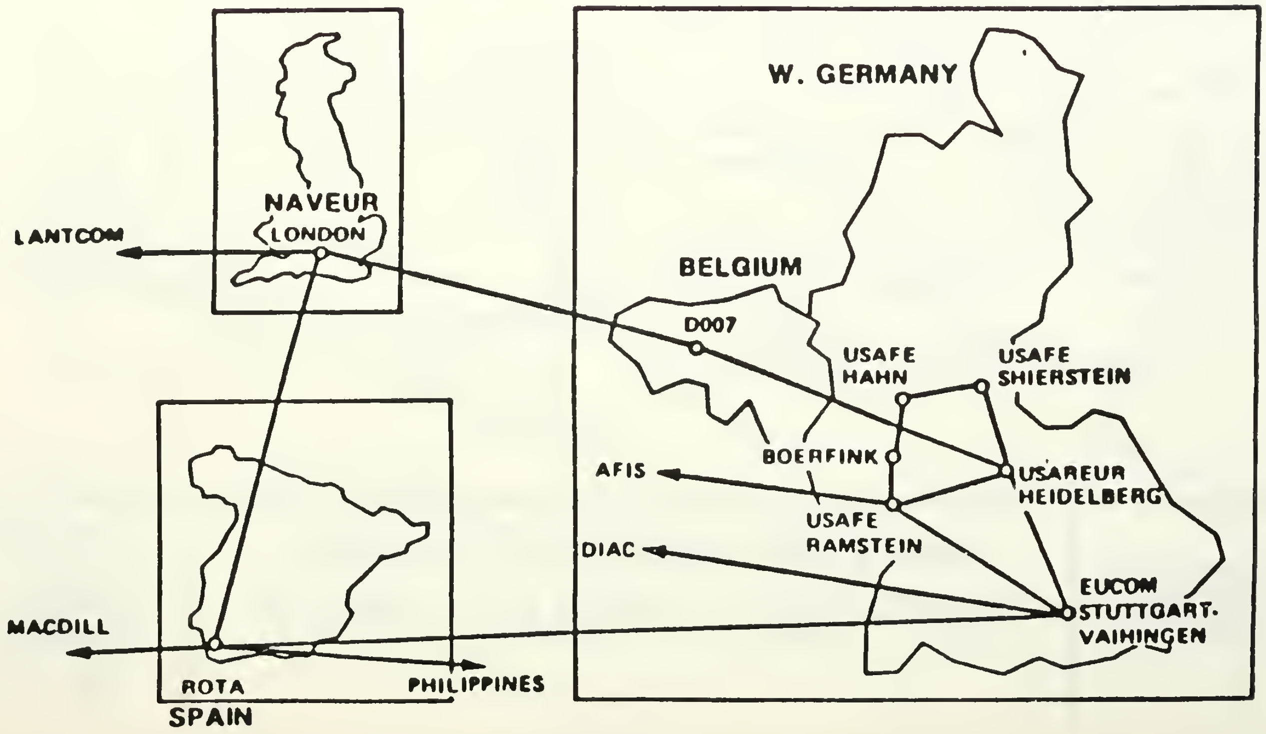
DDN



DEFENSE COMMUNICATIONS AGENCY

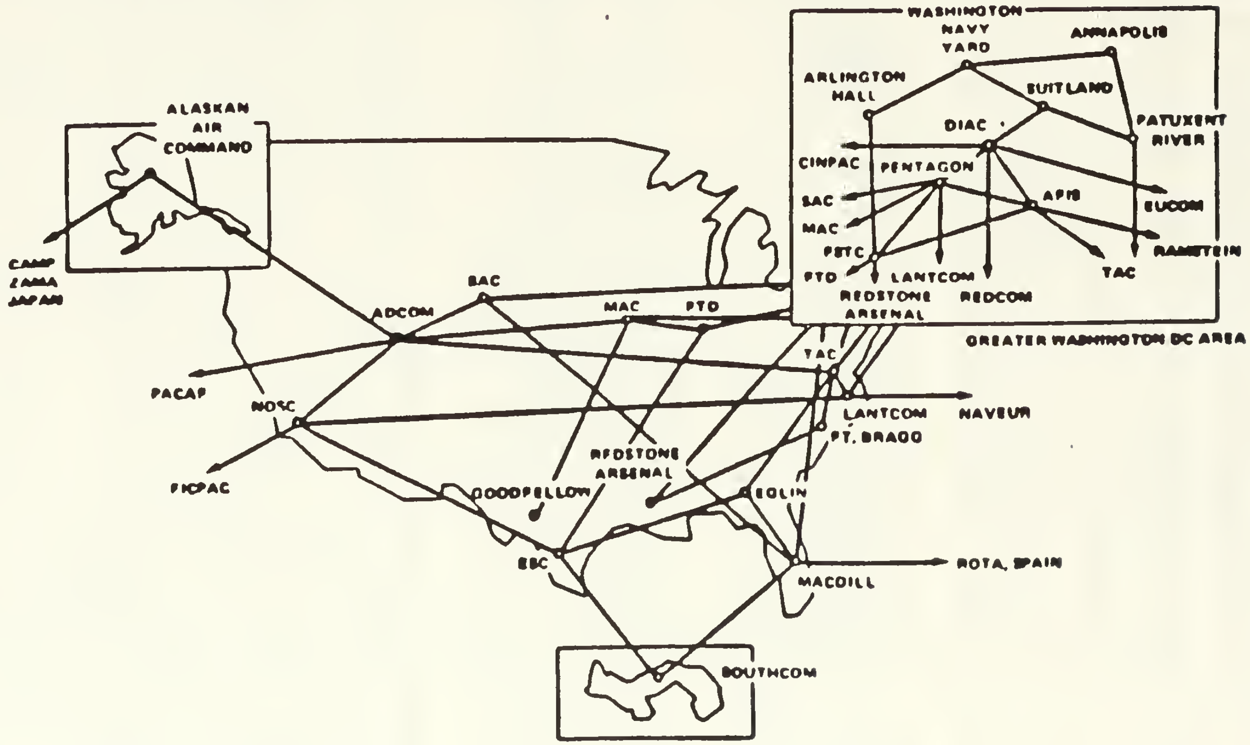
SCINET FUTURE TOPOLOGY
PROPOSED EUROPEAN THEATER

DDN



SCINET FUTURE TOPOLOGY
PROPOSED WESTERN HEMISPHERE

DDN



APPENDIX B

MATHEMATICAL DERIVATION OF DECISION MODEL

This appendix presents a formal demonstration of the premise that the higher the level of authority at which an action to affect usage is undertaken, the greater the actual savings in telecommunications costs.

There are three basic relationships: one technological, one organizational, and one behavioral. They are:

(1) $PS = g(SC)$, $g_1 < 0$; where PS = Potential Savings, SC = Stage of the Life Cycle in which decisions to undertake actions are made. The first derivative, g_1, indicates that potential savings declines as the stage of the life cycle increases. This relationship is technologically based.

(2) $LA = h(SC)$, $h_1 < 0$; where LA = Level of Authority at which a decision to undertake an action at that stage in the life cycle is made. The first derivative, h_1, indicates that as the stage in the life cycle increases, the level of authority at which decisions are made decreases. This relationship is organizationally determined.

(3) $AS/PS = f(PS, LA, ORD)$, $f_1 > 0$, $f_2 > 0$, $f_3 > 0$, where AS = Actual Savings, ORD is the extent to which higher levels of authority (i.e., persons superior to LA) make special efforts to influence the decision to undertake an action. The first derivatives f_1, f_2, and f_3 indicate that actual savings will be closer to potential savings. The greater the potential savings, the greater the level of authority, and the greater the extent to which higher levels of authority try to influence decisions. This is a behavioral relationship.

For simplicity, all functions are assumed to be monotonic increasing or decreasing and to be continuously differentiable. In fact they are discontinuous, because there is only a finite

number of levels of authority and of stages in the life cycle. Taking this into account in the mathematics would not change the essence of the results at all; it would merely convert the final result(s) from monotonic decreasing ones to monotonic non-increasing ones--and complicate the formal derivation considerably.

From (1) and (2) we have:

(4) $PS = g[h^{-1}(LA)]$, and $d(PS)/d(LA)>0$, since

$$\frac{\delta(PS)}{\delta(LA)} = \frac{d(PS)}{d(SC)} * \frac{d(SC)}{d(LA)} = \frac{d(PS)}{d(SC)} * \frac{1}{\frac{d(LA)}{d(SC)}}$$

In which both of the two terms in the right hand side of the last equation are > 0. Note that since (1) and (2) are technologically and organizationally determined, (4) involves no behavioral relationships.

From (3) and (4):

(5) AS = PS f(PS, LA, ORD) where AS = Actual Savings.

$$\frac{d(AS)}{d(LA)} = \frac{d(PS)}{d(LA)} f(PS,LA,ORD)+f_1 \frac{d(PS)}{d(LA)} +f_2 + f_3 \frac{d(ORD)}{d(LA)}$$

All of the first order partial derivatives of f are positive by assumption. $d(PS)/d(LA) > 0$ by prior derivation. $d(ORD)/d(LA)$ is taken to be zero. Hence the conclusion that the $\delta(AS)/\delta(LA) > 0$.

By similar derivation, the derivative $\delta(AS)/\delta(SC)$ can be shown to be negative.

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